Conceptual Study of NGST Science Instruments

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The Next-Generation Space Telescope (NGST), the successor of the Hubble Space Telescope, is scheduled for launch in the year 2008. NGST will make unprecedented discoveries in the realms of galaxy formation, cosmology, stellar populations, star formation, and planetary systems. The telescope is currently in the conceptual design phase of development, and Ames has been involved in defining and studying the scientific instrumentation it will need to conduct its observations.

Along with scientists at the University of Arizona (Kimberly Ennico, Jill Bechtold, George Rieke, Marcia Rieke, Jim Burge, Roland Sharlot, and Rodger Thompson), and in partnership with Lockheed Martin (Larry Lesyna and the Advanced Technology Center staff), Ames has led and completed a conceptual study of the entire NGST scientific instrument complement. This team was one of several international teams selected to study NGST science instruments. The Ames-led team conducted trade studies of specific instrument technologies and implementations, and developed a comprehensive integrated science instrument module (ISIM) concept.

The team found that the science drivers of NGST justify observations from visible (0.4 microns) to far-infrared (35 microns, about 50 times longer than visible to the human eye) wavelengths of light. Imaging capability is required throughout this wavelength range, while spectroscopic capability is required at all wavelengths greater than or equal to 1 micron. Several technologies are key to achieving these capabilities within the cost, schedule, and environmental requirements of the NGST mission. Visible and far-infrared detectors could be developed in time for NGST, and several detector cooling options—including pulse tubes and solid H_2 systems—are viable. The team also found that dispersive slit spectrographs are superior to imaging Fourier Transform spectrometers when complete spatial coverage is not required. Dispersive spectroscopy may be best accomplished with conventional slits or micro-shutter arrays instead of micro-mirror arrays because of the large background rejection (greater than a factor of 1000) required at near-to-far infrared wavelengths.

A complement of seven instrument modules resulted from these scientific and technical considerations by the study team. Two wide-field cameras (each covering about 0.01 square degrees) located directly at the focus of the NGST telescope image visible to near-infrared wavelengths (0.4 to 2.5 microns) in a few broadband filters. A separate visible-light camera covers a smaller field at the maximum resolution of the NGST telescope. The other four modules cover near-to-far infrared wavelengths of light (1 to 34 microns) and are capable of conducting either imaging or dispersive spectroscopic observations with modest fields and good spatial resolution. The capability of providing both imaging and spectroscopy with relatively simple optical designs is enabled by using transmissive dispersion elements (called grisms) for spectroscopy. The conceptual layout of one of these modules is shown in figure 1.

Several technologies must be developed further in order to implement this design concept and to ensure the success of NGST. Increasing the size (number of picture elements) and reducing the noise of infrared detectors will have the greatest scientific

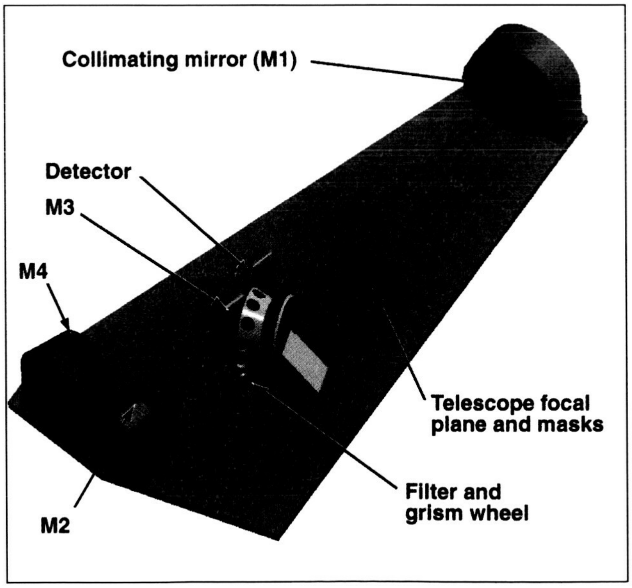

Fig. 1. The optical layout of a single instrument module, which can operate as either a camera or a spectrograph.

impact at relatively modest cost. Ames is already leading this effort for NGST. Reliable closed-cycle cryogenic coolers must also be developed to cool these detectors to temperatures of 4 to 30 kelvin above absolute zero. This task will be eased by the fact that the NGST telescope will always be behind a sun shade and will cool down to approximately 40 kelvin. However, these and all other NGST systems must be very reliable because NGST will be located approximately a million miles from Earth, far beyond the reach of the Space Shuttle, and will not be serviceable by astronauts.

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The SOFIA Telescope Assembly Alignment Simulator

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The NASA Stratospheric Observatory for Infrared Astronomy (SOFIA) is scheduled to begin routine flight operations from Ames in early 2003. To facilitate installation and integration of science instruments with the observatory, a Telescope Assembly Alignment Simulator (TAAS) is being designed and built. Such a facility is required because of the high flight rate, frequent instrument change-outs, and limited access to the telescope cavity.

The TAAS will be an essential part of the Preflight Integration Facility in the SOFIA Science and Mission Operations Center. Before an instrument flies on SOFIA, it will first be mounted on the TAAS to: (a) conform all mechanical and electrical interfaces; (b) prepare the instrument for flight and assess its operational readiness; (c) optically align the instrument with respect to the telescope; and (d) measure the weight and moments of the instrument for use in balancing the telescope assembly. Because the TAAS has such a fundamental role in the preparation of science instruments for flight, a second unit will be permanently stationed in the Southern Hemisphere for use during deployments.

Figure 1 shows an advanced design for the main mechanical structure of the TAAS. Science instruments mount on the instrument-mounting flange, and their associated electronics are housed in a rack attached to the counterweight plate. In order to provide an accurate mechanical reproduction of the telescope interface, the flange assembly and counterweight plate will be exact duplicates of those on SOFIA. The bearing unit assembly allows the science equipment to be rotated through the full range of elevation angles appropriate for SOFIA. The drive system powers the rotation and maintains a selected elevation angle. Three different infrared light sources have been designed to mount on the rear of the TAAS, for use in instrument alignments. A bore-sight camera assembly will be located in the horizontal tube of the TAAS; it will record focus and bore-sight information and facilitate its transfer to the telescope.

Patch panels that are identical to those on the aircraft will be mounted on the sides of the counterweight rack. Through these panels, the instrument will be connected to all essential services, such as vacuum and gas lines, electrical power, and computer communications, to allow a full operational evaluation of the system. The communications will include connection to the computer simulator of the observatory for protocol evaluation and testing of critical software interfaces.

The TAAS is mounted on load cells so that it can measure the weight and moments of instrument focal-plane packages. These measurements will be used to infer the distribution of counterweights required to balance the SOFIA telescope about all three rotational axes for the given instrument configuration. With this information, the balancing procedure aboard the observatory should take less than an hour.

Preliminary design concepts have been developed for all TAAS subsystems, culminating in a successful preliminary design review in September 1999. Some critical subsystems have been prototyped in the laboratory, including the load cells and a special-purpose controller that modulates the signals from the alignment sources.